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PHYSICS.—*Note on the vibration frequencies of elastic systems.* M. D. HERSEY, Bureau of Standards. (Communicated by Louis A. Fischer.)

Introduction. This paper deals with the free vibrations of perfectly elastic bodies. Damping and forced vibrations are excluded from consideration. The purpose is to present the most complete statement, regarding the vibration frequencies of such bodies, that is possible in advance of any knowledge of the geometrical shape of the bodies.

The paper is referred to the attention particularly of persons engaged in acoustics, or in the development of time-keeping devices, or in problems of engineering construction where resonance has to be avoided. Still others, however, may find the paper suggestive in showing what can be done by combining dimensional reasoning with ordinary physical reasoning, in cases where either one alone would be fruitless.

The reasoning is analogous to that of a previous paper entitled The Theory of the Stiffness of Elastic Systems,[1] to which it may be regarded as a sequel, and to which reference must be made for the general conceptions and definitions involved. For convenience, however, the following statement of notation is given:

θ = temperature

E = Young's modulus; $\alpha = \frac{1}{E}\frac{dE}{d\theta}$

[1] Journ. Wash. Acad. Sci., **6**: 569–575. 1916.

μ = shear modulus; $\beta = \frac{1}{\mu}\frac{d\mu}{d\theta}$

L = length; $\gamma = \frac{1}{L}\frac{dL}{d\theta}$

m = mass; ρ = density

σ = Poisson's ratio

$\Phi = \Phi(\sigma)$; $\Phi' = \frac{d}{d\sigma}\Phi(\sigma)$; etc.

$F = F(R, \sigma)$; $F' = \frac{\partial}{\partial \sigma} F(R, \sigma)$

$R = \frac{m_1}{m_1 + m_2}$; $\eta = \frac{S_1}{S_1 + S_2}$

Subscripts 1 and 2 refer to the members of a coupled system.

S = stiffness (ratio force to displacement)

S_t = torsional stiffness (ratio moment to angle)

n = frequency of free vibration

$\dot{n} = \frac{1}{n}\frac{dn}{d\theta}$; $\dot{S} = \frac{1}{S}\frac{dS}{d\theta}$; etc.

c, C, C_t, C_1, C_2, C_{12} = dimensionless "shape factors," i.e., constants fixed by Poisson's ratio and the generalized shape.

The most important results of this paper are to be found in the four formulas (1), (4), (11), and (12), giving respectively the frequency of a single body, the change in frequency with temperature, the frequency of a coupled system, and the change in this frequency with temperature.

General formulas for frequency of a single body. The vibration frequency for all bodies of the same generalized shape (it will be recalled that this implies not only geometrical similarity but also a similar distribution of density and the other properties of the material) may be written

$$\left.\begin{aligned} n &= \frac{1}{L}\sqrt{\frac{E}{\rho}}\,\Phi_0(\sigma) = \frac{1}{L}\sqrt{\frac{\mu}{\rho}}\,\Psi_0(\sigma) \\ &= \sqrt{\frac{LE}{m}}\,\Phi(\sigma) = \sqrt{\frac{L\mu}{m}}\,\Psi(\sigma) \end{aligned}\right\} \qquad (1)$$

The first two results come at once from dimensional reasoning on the assumption that the absolute size L, the density ρ, together with any two of the three elastic constants E, μ, and σ, form a complete set of independent variables. Those two results, except for the explicit mention of Poisson's ratio, will be familiar to any one who has consulted Lord Rayleigh's writings on Sound. The transition to the last two results is obvious, and these will be more useful for some of the present purposes, because they involve a smaller number of quantities that are affected by temperature. This happens because of the physical fact that the mass of a body does not sensibly alter with temperature, whereas both the length and density do. The functions Φ_0, Φ, etc., are unknown, but if necessary could be determined by model experiments; thus, for example, Φ_0 would be found by plotting observed values of $n\,L\sqrt{\frac{\rho}{E}}$ against known values of σ.

General formula for change in frequency of a single body with temperature. Differentiating the second part of (1) logarithmically, treating m as a constant, and simplifying mathematically without introducing any further physical information, gives

$$\left.\begin{aligned} \dot{n} &= \frac{\Phi'}{\Phi}\frac{d\sigma}{d\theta} + \tfrac{1}{2}(\alpha+\gamma) \\ &= \frac{\Psi'}{\Psi}\frac{d\sigma}{d\theta} + \tfrac{1}{2}(\beta+\gamma) \end{aligned}\right\} \qquad (2)$$

In case the first term vanishes, a simple result is already available. This will happen for pure bending or stretching, for pure twisting or shearing, and for materials, if any such exist, in which Poisson's ratio does not change with temperature. For, with pure bending etc., Φ is constant, so that $\dot{n} = \frac{1}{2}(\alpha+\gamma)$; while, with pure twisting, etc., Ψ is constant, so that $\dot{n} = \frac{1}{2}(\beta+\gamma)$. In general, however, some physical law must now be made use of to evaluate $\frac{d\sigma}{d\theta}$.

The foregoing results, once it is stipulated which one of the multiple values of the several constants is to be understood by a given symbol, are perfectly applicable to heterogeneous and

anisotropic bodies; nor need the vibrations be small enough to be isochronous, provided the restriction to the same generalized shape is taken to include the deformations. But, now, for homogeneous, isotropic bodies

$$\sigma = \frac{1}{2}\frac{E}{\mu} - 1 \tag{3}$$

Differentiating (3), and substituting the result in (2), gives finally

$$\left.\begin{aligned} \dot{n} &= \tfrac{1}{2}\left[(c+1)\,\alpha - c\beta + \gamma\right] \\ \text{in which} \\ c &= 2\,(1+\sigma)\,\frac{\Phi'}{\Phi} = (1+\sigma)\,\frac{d}{d\sigma}\log\left(\frac{mn^2}{LE}\right) \\ &= 2\,(1+\sigma)\,\frac{\Psi'}{\Psi} - 1 = (1+\sigma)\,\frac{d}{d\sigma}\log\left(\frac{mn^2}{L\mu}\right) - 1 \end{aligned}\right\} \tag{4}$$

The simplicity of equation (4) is noteworthy; it shows that, for bodies made of materials for which $\alpha, \beta,$ and γ are known, the effect of temperature on frequency can be determined empirically without altering the temperature of the models; and, therefore, without any restrictions on the thermal properties of the materials the models are made of. Note that in plotting $\frac{mn^2}{LE}$ or $\frac{mn^2}{L\mu}$ against σ to determine c as a function of σ graphically, relative values are sufficient; for the existence of an unknown constant numerical factor will not alter the slope of a logarithmic plot. The same remark applies below, wherever similar expressions occur.

From (4) the condition for temperature compensation is that

$$\frac{\beta}{\alpha} = 1 + \frac{1}{c}\left(1 + \frac{\gamma}{\alpha}\right) \tag{5}$$

When γ is small compared to α (for steel γ is about 1/25 of α), $\frac{\beta}{\alpha} = 1 + \frac{1}{c}$. The two methods of compensation suggested in the previous paper—altering the composition of the material, or altering the geometrical shape of the body—are equally applicable here.

Nothing that has been said prevents Φ in (1), and therefore c in (5), from being a multivalued function, corresponding to the existence of more than one mode of vibration. From this it might be imagined that the condition for compensation (5) would not apply to more than one mode of vibration at a time; so that, if an alloy were so chosen as to compensate the fundamental, the pitch of the harmonics would alter with temperature. Closer examination shows that, for any two frequencies which stand in a constant ratio $\frac{n_1}{n_2} = k$, where k is independent of Poisson's ratio, the values of c will be identical, and compensation will be possible simultaneously, if possible at all.

The relation of frequency to stiffness. From equation (3) of the previous paper, $S = LE\,\phi(\sigma) = L\mu\,\psi(\sigma)$. Comparing with (1) above,

$$n = \sqrt{\frac{S}{m}}\, f(\sigma) \tag{6}$$

in which the form of f will depend on the generalized shape.

In passing it may be noted that the corresponding expressions in terms of torsional stiffness are sometimes preferable. It can be shown that the torsional stiffness or rigidity

$$S_t = L^3 E\,\phi_t(\sigma) = L^3\mu\,\psi_t(\sigma) \tag{7}$$

so that

$$n = \frac{1}{L}\sqrt{\frac{S_t}{m}}\, f_t(\sigma) \tag{8}$$

From (7), also,

$$\left.\begin{aligned} \dot{S}_t &= (C_t + 1)\,\alpha - C_t\beta + 3\,\gamma \\ \text{in which} \quad C_t &= (1+\sigma)\frac{\phi_t'}{\phi} = (1+\sigma)\frac{d}{d\sigma}\log\left(\frac{S_t}{L^3E}\right) \\ &= (1+\sigma)\frac{\psi_t'}{\psi} - 1 = (1+\sigma)\frac{d}{d\sigma}\log\left(\frac{L^3\mu}{S_t}\right) - 1 \end{aligned}\right\} \tag{9}$$

The use of (7), for example, as a recipe for model experiments, would render unnecessary the St. Venant theory of the torsion of

prisms, so far as any practical application to the stiffness of beams or galvanometer suspensions is concerned.

Formulas for frequency of a coupled system. From (6),

$$n = \sqrt{\frac{S_1 + S_2}{m_1 + m_2}}\, f(\sigma) \tag{10}$$

because $m = m_1 + m_2$, and, for forces acting at the coupling, $S = S_1 + S_2$ (equation (11) of previous paper). Since f depends on the generalized shape, it will be different for different values of the ratio R, and in any case it is multivalued.

In the particular case of two bodies having the *same* generalized shape and σ, S_1 and S_2 of (10) can be replaced by their equivalents in terms of n_1 and n_2 by virtue of (6), with the result

$$n = \sqrt{R\, n_1^2 + (1 - R)\, n_2^2}\; F(R, \sigma) \tag{11}$$

The function F depends only on the generalized shape; not at all on the absolute sizes, masses, or elastic moduli of the bodies.

Formulas for change in frequency of coupled system with temperature. Differentiating (10) logarithmically gives, in the case of two bodies of different generalized shapes but of the *same material*,

in which

$$\left.\begin{aligned} \dot{n} &= \tfrac{1}{2}\left[(K+1)\,\alpha - K\,\beta + \gamma\right] \\ K &= \eta\, C_1 + (1 - \eta)\, C_2 + C_{12} \\ C_{12} &= 2\,(1+\sigma)\frac{f'}{f} = (1+\sigma)\frac{d}{d\sigma}\log\left(\frac{mn^2}{S}\right) \end{aligned}\right\} \tag{12}$$

and in which C_1 and C_2 are the appropriate values for the ordinary shape factor C for stiffness, as given in the previous paper; viz.,

$$\begin{aligned} C_1 &= (1+\sigma)\frac{\phi_1'}{\phi_1} = (1+\sigma)\frac{d}{d\sigma}\log\left(\frac{S_1}{L_1 E_1}\right) \\ &= (1+\sigma)\frac{\psi_1'}{\psi_1} - 1 = (1+\sigma)\frac{d}{d\sigma}\log\left(\frac{S_1}{L_1 \mu_1}\right) - 1, \end{aligned}$$

with a like expression for C_2.

For two bodies of the same material and, also, of the same generalized shape, differentiating (11) gives for K in (12) the more simple expression.

$$K = c + 2(1 + \sigma)\frac{F'}{F} \tag{13}$$

which does not require observations of stiffness.

In any event the term C_{12} vanishes when complex stresses are absent, for S will then be independent of Poisson's ratio, and f therefore a constant. But C_{12} is the only term in (12) which involves the masses of the bodies in any way. Hence the curious conclusion that, when complex stresses are absent, $\dot{n}$ will be independent of both the absolute mass and the mass distribution.

SOME EXAMPLES

1. *Waves in an infinite elastic plate.* The most recent work on this subject[2] affords an instance of equation (1); for while the result as published does not resemble equation (1), it reduces to it identically on setting $\Phi_0(\sigma) = \pi(2k + 1)\sqrt{\frac{1-\sigma}{(1+\sigma)(1-2\sigma)}}$ in which k is any integer, the length L of equation (1) being taken to be the thickness of the plate.

2. *Resonance periods of similar structures.* Let quantities pertaining to the original, full-sized structure be distinguished by the subscript 0; while those referring to the model are without subscripts. Then by (1) and (6)

$$\frac{n_0}{n} = \frac{L}{L_0}\sqrt{\frac{E_0}{E}}\sqrt{\frac{\rho}{\rho_0}} = \sqrt{\frac{S_0}{S}}\sqrt{\frac{m}{m_0}}$$

the first form being preferable when stiffness measurements can not be made; the second when the properties of the material are not known.

3. *Temperature compensation of ordinary tuning fork.* For any case of pure bending or stretching, β can not enter (4); hence $c = 0$, and $\dot{n} = \frac{1}{2}(\alpha + \gamma)$, which agrees with (2). Assuming α negative and γ positive, as is true for steel, compensa-

[2] LAMB, H. Proc. Roy. Soc. **93** (A): 114–128, eq. (80). 1917.

tion requires that their numerical values be made equal. There were some persons who took the trouble to construct a certain tuning fork of invar, in hopes of diminishing its temperature coefficient; as would be seen from the above equation, this only made matters worse.

4. *Shrill tuning fork.* For any case of pure twisting or shearing, such as the very short stubby forks used for producing inaudible notes, α cannot enter (4); $c = -1$, and $\dot{n} = \frac{1}{2}(\beta + \gamma)$.

5. *Telephone diaphragm.* For the case of a thin flat circular disc clamped at the edge, and so approximating a telephone diaphragm, the expression for c which would be obtained from model experiments in accordance with (4), if it were not already available as a result of integration,[3] is $c = \frac{2\sigma}{1-\sigma}$. With $\sigma = 0.3$, $c =$ about $\frac{6}{7}$, so that (4) becomes $\dot{n} = \frac{13}{14}\alpha - \frac{3}{7}\beta + \frac{1}{2}\gamma$. Complete compensation would require that β be about twice α. (Steel samples have been found, with $\frac{\beta}{\alpha}$ considerably greater and also less than 2.) But note from (4) that the α and β terms will enter with opposite signs whenever C is positive. Since C is positive for the disc shape, it appears that the temperature coefficient of a disc will always be small compared with that of a tuning fork of the same material, no matter what that material is.

6. *Spring with distributed mass.* If the mass is uniformly distributed in the direction of the displacement and remains so during the deformation, it may be shown by integration that $n = \sqrt{\frac{S}{m}}\left[\frac{1}{2\pi}\left(1 + \frac{1}{3}\frac{m_0}{m}\right)^{-\frac{1}{2}}\right]$. This expression is consistent with (6); $f(\sigma)$ being a constant depending on the ratio of the mass of the spring, m_0, to the attached mass, m.

[3] Rayleigh in his Theory of Sound, vol. I, § 221 a, gives for the disc a formula which, in present notation, may be written $n = \sqrt{\frac{LE}{m}}\left[0.833\left(\frac{h}{L}\right)^{\frac{3}{2}}(1-\sigma^2)^{-\frac{1}{2}}\right]$. Here L is the diameter and h the thickness. Thus $\Phi(\sigma) = \text{const.}\,(1-\sigma^2)^{-\frac{1}{2}}$. Differentiating as directed by (4) gives the expression for c. (In footnote 6 of previous paper replace 32π by $\frac{32}{3}\pi$.)

7. *Balance wheel of a watch.* The well-known expression $n = \frac{1}{2\pi}\sqrt{\frac{S_t}{I}}$ for the case of a weightless spring acting on a rigid mass of moment of inertia I, may also be written $n = \frac{1}{r}\sqrt{\frac{S_t}{m}}\frac{1}{2\pi}$ in which r is the radius of gyration. This agrees with (8). Differentiating, $\dot{n} = \frac{1}{2}\dot{S}_t - \dot{r}$. For the hair spring (pure bending), (9) becomes $\dot{S}_t = \alpha + 3\gamma$, hence for the balance wheel $\dot{n} = \frac{1}{2}\alpha + \frac{3}{2}\gamma - \dot{r}$. The condition for compensation is therefore that the radius of gyration shall be constrained to vary with temperature at the rate $\dot{r} = \frac{1}{2}(\alpha + 3\gamma)$.

8. *Two springs coupled together.* Let spring 1, strained purely by twisting, be coupled to spring 2, which is strained purely by bending; and let both springs be made of the same material. Then ψ_1 and ϕ_2 are constants, so that $C_1 = -1$, $C_2 = 0$, $C_{12} = 0$; $\therefore K = -\eta$, and (12) becomes $\dot{n} = \frac{1}{2}[(1-\eta)\alpha + \eta\beta + \gamma]$. When the twisted spring is stiffer than the bent spring, the β term predominates, and vice-versa. For springs equally stiff, $\eta = \frac{1}{2}$, $\therefore \dot{n} = \frac{\alpha}{4} + \frac{\beta}{4} + \frac{\gamma}{2}$. For two helical springs, $C_1 = C_2 = -1$, so that $\dot{n} = \frac{1}{2}(\beta + \gamma)$; for two leaf springs or elliptical springs, $C_1 = C_2 = 0$, so that $\dot{n} = \frac{1}{2}(\alpha + \gamma)$. These results, including the above formula for $\dot{n}$ in terms of α, β, γ, and η, and subject to the limitations stated, are true independently of the shapes and mass distributions of the two bodies, as well as of their absolute sizes, masses, and elastic moduli.

CRYSTAL OPTICS.—*Dispersion and other optical properties of carborundum.* H. E. MERWIN, Geophysical Laboratory.

Along the edge of a very pale green carborundum crystal two areas, each about 0.5 mm. square, were found which were suitable for measuring the ordinary refractive index. The angles, measured from the base, were 32° 13′ and 34° 15′. The refractive index for the extraordinary ray was found by measurements on the interference figure[1] of a colorless plate 0.675 mm. thick and about 3 mm. square.

[1] See BAUER, M. Neues Jahrb., **2**: 49. 1882–83; also Journ. Wash. Acad. Sci., **4**: 533 and 538. 1914.

The dispersion and birefringence are both much less than those calculated by L. E. Jewell[2] from interference phenomena. The birefringence corresponds closely to Becke's[3] measurement, but the refractive index, ω_{Na}, is less than his rough measurements indicated.

TABLE 1

INDICES OF REFRACTION OF CARBONRUNDUM

λ	ω	ε
μμ		
755	2.616	2.654
745	2.618	2.656
726	2.622	2.660
700	2.627	2.666
671	2.633	2.673
589	2.654	2.697
535	2.675	2.721
486	2.700	2.749
468	2.713	2.763
434	2.741	2.794
422	2.753	2.808
416	2.757	2.812

Microscopical study of several samples of granular carborundum has revealed no definite variations in the refractive index for red light, even in grains of different color. Coarse material which is very black may be, when powdered—grains a few hundredths of a millimeter in diameter—fairly transparent. Bluish grains are notably pleochroic, some from light blue to dark blue, some from olive green to greenish blue. The ω is the more strongly absorbed. Coarse black crystals intimately associated with graphite appear to contain small amounts of material which give small grains a grayish to bluish color by transmitted light, but this material, in all the grains so far observed, has been submicroscopic in size.

The results for ω in table 1 were obtained as averages from the two prisms. The observed values for one prism were 0.003–0.005 higher than for the other. But inasmuch as one face of

[2] Quoted by TONE, in Mineral Industry, **16**: 153. 1907.
[3] Zeitschr. Kryst., **24**: 524. 1895.

each prism showed curvature of 5′ the differences should be regarded as observational. The difference[4] $\epsilon-\omega$ is probably not in error more than ± 0.001.

A recent notice of a study of the physical properties of carborundum by O. Weigel has been published,[5] but no details are available.

MINERALOGY.—*The nomenclature and classification of the native element minerals.* EDGAR T. WHERRY,[1] National Museum.

In many respects it would be difficult to improve upon the nomenclature and classification of native elements worked out in Dana's System of Mineralogy, yet with the advance of scientific knowledge new points of view are certain to arise and newly discovered species to demand place in any scheme, so that changes must be introduced. A few suggestions in this direction are here put forward, for discussion, criticism, or whatever fate they may seem to readers to deserve.

NOMENCLATURE

The names adopted by Dana are as a rule satisfactory, but wherever considerations of simplicity, consistency, and clearness suggest the desirability of changes from his usage, there should be no hesitation about introducing others.

When an element is known to occur in nature in but one form, no name different from that used for it in chemistry is needed; but several elements show polymorphous forms, and these have heretofore been distinguished by adding either: a suffix, as in sulfur and sulfur*ite;* a prefix, as in palladium and *allo*palladium; Greek letters as prefixes, as in α-sulfur and β-sulfur; or adjectives, as in *yellow* phosphorus and *monoclinic* selenium. The last method, using crystallographic adjectives, is preferable, because it can be employed alike in all cases, and its systematic introduction into mineralogical nomenclature is therefore recommended.

[4] The value for the D-line was checked on a thinner plate and, roughly for lithium light, on grains in immersion liquids.

[5] WEIGEL, O. Chem. Abstr., **11**: 1066. 1917.

[1] Transferred August 16th to the Bureau of Chemistry.

Many minerals consist of isomorphous mixtures of two or more elements. Two different methods of deriving names for these have been used in the past: first, by combining the names of the elements present, as selentellurium for selenium-bearing tellurium, platiniridium for platinum-bearing iridium, and nickeliron for nickel-bearing iron; and second, by introducing arbitrary or special terms, as volcanite for selenium-bearing sulfur, sisserskite for iridium-bearing osmium, and porpezite for palladium-bearing gold. As one element is almost invariably greatly in excess over the others, these should be regarded as varieties, rather than elevated to the rank of species. It is, further, believed to be highly desirable that species and varieties be distinguished by the terminology applied to them. As arbitrary or special names, including in this case the names of chemical elements, are generally accepted as appropriate for species, it is thought that their application to varieties should be discouraged, and such names as volcanite, sisserskite, and porpezite be discarded.

The use of chemical prefixes with species names in general is also objectionable because of the resulting inconsistencies and ambiguities, as emphasized by Prof. A. F. Rogers;[2] to this the native elements are no exception. For example, the mineral termed allemontite by Haidinger in 1845, a variety of arsenic containing a small amount of isomorphous antimony, has been called antimonarsenic by some mineralogists, and arsenantimony by others. When two diametrically opposed terms are thus applied to a single substance, it is evident that neither can be regarded as clearly expressing its nature, or accepted to the exclusion of others. Many other minerals, as amalgam, iridosmine, awaruite, etc., show similar confusion in their nomenclature.

To simplify matters and to make the terms as unambiguous as possible, the plan recommended by Professor Rogers in the paper cited is favored: that all varieties due to isomorphism be named by means of adjectives, formed by adding the suffix *iferous* to the names of the elements present in smaller amounts (the names being put in the Latin form when necessary for euphony).

[2] Proc. Am. Phil. Soc., **52**: 610. 1913.

CLASSIFICATION

In Dana's System the native elements are first split up into three divisions, non-metals, semi-metals, and metals. The first two divisions, however, show no pronounced differences, and various inconsistencies arise in apportioning the elements between them. For instance, graphite, which is classed as a non-metal, has a more metallic luster and is a better conductor of electricity than arsenic, which is classed as a semi-metal. Selenium is regarded as a non-metal when monoclinic, and as a semi-metal when rhombohedral; and the same would have to be done with sulfur, arsenic, and antimony, were all of their forms included, for these three crystallize in one or more forms with so-called non-metallic, and others with so-called semi-metallic properties. But the illogical character of this arrangement, which assumes that the element changes its fundamental nature on appearing in an unusual crystallized condition, is evident. The distinction between the non- and semi-metals appears, then, to be rather artificial, and both convenience and accuracy suggest that it be abandoned.

The major divisions are in turn subdivided into groups. Throughout the greater part of Dana's System, the groups are composed of minerals of close chemical and crystallographic relationships. Among the elements, however, this arrangement is to some extent departed from, resulting in the establishment of a "carbon group," in which crystallographic similarity is lacking, and a "platinum group," which includes two types of crystallization. As no good reason for this departure appears to exist, it is recommended that these groups be placed on a crystallographic basis. The carbon group then yields an isometric diamond group, into which several recently discovered non-metallic elements fall, and a hexagonal-trigonal graphite group, which may for simplicity be united with the crystallographically identical arsenic group; in graphite $c = 1.386$, which lies between the value for arsenic, 1.401, and that for antimony, 1.324; all three elements have basal cleavage.

Similarly, the platinum group may be split into an isometric and a hexagonal-trigonal group, while tin, which crystallizes in

a still different system, the tetragonal, is assigned to a group by itself.

In listing groups it is thought best to give those of the highest crystallographic symmetry first place, and to arrange the others in the order of decrease in symmetry.

A table of native elements based on the above recommendations follows. Its criticism by anyone interested in the systematic arrangement of mineralogic data will be welcomed.

NOTES ON THE TABLE

The first column includes the names of the species and varieties worked out according to the principles above outlined and recommended for adoption. The composition of each species and variety is given in the second column, isomorphous replacement being represented by a comma, and the element present in largest amount in each case being placed first.

Column 3 contains reasons for the names or arrangements adopted, synonyms (in quotations), and references for the minerals not listed by Dana in either the System of Mineralogy (1892) or the three Appendixes (1899, 1909, 1915).

NATIVE ELEMENT MINERALS.	The chemical elements occurring in nature in the free state.	
NON-METALS (INCLUDING "SEMI-METALS")	Combined for simplicity.	
DIAMOND GROUP. ISOMETRIC		New; includes all non-metals and semi-metals with isometric crystallization, arranged in order of the periodic system.
Diamond (isometric carbon)	C	The retention of the arbitrary name diamond is an exception to the rule for naming polymorphs, but is justified by usage.
Massive	C	"Bort."
Black massive	C	"Carbonado."
Phosphorus, isometric	P	"Yellow phosphorus," "β-phosphorus." Meteoritic; very doubtful.
Arsenic, isometric	As	"Yellow arsenic." Occurrence in nature reported by Vernadskii, *Opuit Opisatel'noi Mineralogii* (Descriptive Mineralogy) **1**, 1908; *Centr. Min. Geol.*, **1912**: 762. (Not in Dana.)
Tantalum, columbiferous	Ta, Cb	

GRAPHITE GROUP. HEXAGONAL-TRIGONAL		New; a combination of graphite with Dana's tellurium-arsenic group, arranged in order of the periodic system.
Graphite (trigonal carbon)	**C**	Name retained for the same reason as that of diamond; "Cliftonite" is a meteoritic paramorph of graphite after diamond.
Arsenic, trigonal	**As**	
Antimoniferous	**As, Sb**	"Allemontite" (Dana No. 9). Classed as a species by Dana, but there is no evidence that it is anything but a variety of arsenic containing a variable amount of isomorphous antimony.
Antimony	**Sb**	
Arseniferous	**Sb, As**	
Bismuth	**Bi**	
Tellurium, trigonal	**Te**	
Seleniferous	**Te, Se**	"Selentellurium" (Dana No. 6). Classed as a species by Dana, but there is no evidence that it is anything but a variety of tellurium containing a variable amount of isomorphous selenium. This selenium is present in a trigonal form, which has not yet been discovered to exist independently in nature, but has been produced artificially.
ORTHORHOMBIC-SULFUR GROUP		The "Sulphur group" of Dana.
Sulfur, orthorhombic	**S**	The spelling of this name with *f* instead of *ph* is justified by history and usage and has been adopted by the American Chemical Society.
Seleniferous	**S, Se**	"Selensulphur" (Dana No. 4), "volcanite." Classed as a species by Dana, but there is no definite evidence that it is anything but a variety of sulfur containing a variable amount of isomorphous selenium; this selenium is present in an orthorhombic form as yet unknown independently.
Telluriferous	**S, Te**	"Tellursulphur"
MONOLCINIC-SULFUR GROUP		New; includes all non-metals and semimetals with monoclinic crystallization.
Sulfur, monoclinic	**S**	"β-sulfur," "γ-sulfur." β-sulfur is common around volcanoes, but is preservable only as a paramorph of orthorhombic sulfur; γ-sulfur has been reported to occur in nature by Vernadskii, *Opuit*

		Opisatel'noi Mineralogii, **1**, 1908; *Centr. Min. Geol.*, **1912**: 761; and still another form in stable crystals has been described by Suzuki, *Beitr. Min. Japan*, **5**: 231. 1915. (Not in Dana.)
Selenium, monoclinic	**Se**	"α-selenium"
Arsenic, monoclinic	**As**	"Arsenolamprite." Crystallization not certain.
COLLOIDAL GROUP. AMORPHOUS.		New; includes all non-metals and semimetals occurring in the amorphous state.
Carbon, amorphous	**C**	The coloring matter of black sediments.
Silicon, dispersoidal	**Si**	Suggested to be the cause of the color of smoky quartz, though without statement of evidence, by Königsberger and Müller, *Centr. Min. Geol.*, **1906**: 73, note. (Not in Dana.)
Phosphorus, amorphous	**P**	Occurrence in nature reported by Vernadskii, *Opuit Opisatel'noi Mineralogii*, **1**, 1908; *Centr. Min. Geol.*, **1912**: 762. (Not in Dana.)
Sulfur, amorphous	**S**	"Sulfurite." A precipitate in sulfur-spring water; also a volcanic product. (Not in Dana.)
Selenium, amorphous	**Se**	Occurrence in nature pointed out by Zambonini, *Mineralogia Vesuviana*, p. 24, 1910. (Not in Dana.)
Iodine, amorphous	**I**	Occurrence in nature reported by Skey in 1877; Vernadskii, *Centr. Min. Geol.*, **1912**: 762. (Not in Dana.)
METALS		Includes the native elements of predominantly basic character.
COPPER GROUP. ISOMETRIC		When the minerals of Dana's "gold group" are arranged according to the periodic system, copper comes first and the group is here named after it.
Copper	**Cu**	Wire copper, a variety, is probably a paramorph of crystalline copper after amorphous copper which has been forced through small openings while soft, corresponding to wire silver. (See below.)
Argentiferous	**Cu, Ag**	
Mercuriferous	**Cu, Hg**	Brush, *Am. Journ. Sci.*, [2], **31**: 354. 1861, throws doubt on the occurrence of this variety.

Ferriferous	Cu, Fe	
Silver	Ag	Wire silver, a common variety, is a paramorph of crystalline silver after amorphous silver, which has been forced through small openings while soft. Mügge, *Neues Jahrb. Min. Geol.*, **1913** (II): 1.
Cupriferous	Ag, Cu	
Auriferous	Ag, Au	"Küstelite"
Mercuriferous	Ag, Hg	"Amalgam," in part; "arquerite," "bordosite," "kongsbergite;" included, along with argentiferous mercury, in the species "amalgam" by Dana, but there is no definite evidence that it is anything but a variety of silver containing variable amounts of isomorphous mercury.
Gold	Au	Wire gold, a variety, is probably a paramorph of crystalline gold after amorphous gold which has been forced through small openings while soft, corresponding to wire silver. (See above.)
Cupriferous	Au, Cu	
Argentiferous	Au, Ag	"Electrum." Given a special name by the ancients, though recognized by them to be only an argentiferous variety of gold.
Mercuriferous	Au, Hg	Occurrence in nature reported by Schmitz, *Z. deut. geol. Ges.*, **4**: 137. 1852. (Not in Dana.)
Rhodiferous	Au, Rh	"Rhodite."
Palladiferous	Au, Pd	"Porpezite."
Iridiferous	Au, Ir	Occurrence in nature reported by Wöhler, 1834; Vernadskii, *Centr. Min. Geol.*, **1912**, 760; confirmed by Chernik, *Trav. Mus. Acad. Sci. Petrograd*, **6**: 49. 1912. (Not in Dana.)
Platiniferous	Au, Pt	Occurrence in nature discovered by Chernik, *Trav. Mus. Acad. Sci. Petrograd*, **6**: 49. 1912. (Not in Dana.)
Mercury	Hg	"Quicksilver." Liquid at ordinary temperatures, but crystallizes at −39°C.
Argentiferous	Hg, Ag	"Amalgam" in part. Included, along with mercuriferous silver, in the species "amalgam" by Dana, but there is no definite evidence that it is anything but a variety of mercury containing variable amounts of silver, either in solid, isomorphous form, or dissolved, liquid form.

Auriferous	Hg, Au	"Gold-amalgam" in part. The gold is either in solid, isomorphous form, or dissolved, liquid form.
Lead	Pb	
IRON GROUP. ISOMETRIC		When the minerals of Dana's "platinum-iron group" are arranged according to the periodic system, iron comes first, and the group is here named after it.
Iron	Fe	"Ferrite." Native iron, both meteoritic and terrestrial, may contain isomorphous copper, vanadium, chromium, manganese, cobalt, nickel, ruthenium, palladium, iridium, platinum, and perhaps other metals; but only two of these occur in sufficient amount to be regarded as giving rise to definite varieties.
Nickeliferous	Fe, Ni	"Edmonsonite," "kamacite," "lamprite," "plessite," "taenite." Meteoritic; the varieties are chiefly separated on the basis of structure.
Platiniferous	Fe, Pt	Occurrence in nature reported by Osann, *Ann. Phys. Chem.*, **14**: 329. 1827. (Not in Dana.)
Nickel, ferriferous	Ni, Fe	"Awaruite," "josephinite," "octibbehite," "souesite." Both meteoritic and terrestrial; the minerals referred to by the synonyms have been regarded as separate species, but there is no definite evidence that they are anything but varieties of nickel containing small, variable, amounts of isomorphous iron.
Palladium, platiniferous	Pd, Pt	"Native palladium." May also contain small amounts of isomorphous iridium.
Iridium, platiniferous	Ir, Pt	"Native iridium." Named "iridium" by Dana and others, although analyses cited show the presence of at least 19% of isomorphous platinum and smaller amounts of other metals, especialy copper and palladium; pure iridium is not known to occur in nature.
Platinum, ferriferous	Pt, Fe	"Native platinum." Named platinum by Dana and others, although analyses show the presence of considerable amounts of isomorphous copper, gold, iron, nickel, rhodium, palladium, osmium, and iridium; only two of

	these, iron and iridium, occur in sufficient amount to be regarded as giving rise to definite varieties.
Iridiferous.....Pt, Ir	Included by Dana partly under "iridium" and partly under "platinum."
TRIGONAL-PALLADIUM GROUP.....	New; includes zinc, classed by Dana as a semi-metal, and the trigonal minerals of the platinum-iron group.
Zinc.....Zn	Occurrence in nature doubtful.
Palladium, trigonal.....Pd	"Allopalladium." May contain isomorphous silver, gold, and platinum, although none of these occur in sufficient amounts to be regarded as giving rise to definite varieties.
Osmium, iridiferous.....Os, Ir	"Dark iridosmine," "sisserskite." Included, along with the following mineral, in the species "iridosmine" by Dana; but there is no definite evidence that it is anything but a variety of trigonal osmium containing variable amounts of iridium and perhaps other metals.
Iridium, osmiferous.....Ir, Os	"Light iridosmine," "nevyanskite." Included, along with the preceding variety, in the species "iridosmine" by Dana; but there is no definite evidence that it is anything but a variety of trigonal iridium; may contain isomorphous copper, iron, ruthenium, rhodium, palladium, osmium, and platinum; of these only osmium occurs in sufficient amount to be regarded as giving rise to a definite variety.
TIN GROUP. TETRAGONAL.....	New; included by Dana in the gold group but here separated on the basis of different crystallization.
Tin.....Sn	Occurrence in nature never proved beyond doubt, although there is a specimen in the U. S. National Museum from placers in California which has every appearance of being a natural product.
COLLOIDAL GROUP. AMORPHOUS	New; includes all metals occurring in the amorphous state.
Silver, amorphous.....Ag	Known to early German miners, but its character was first recognized by Cornu, *Z. Chem. Ind. Kolloide*, **4**: 187. 1909. (Not in Dana.)

Gold, amorphous.....**Au**	Occurrence in nature reported by Cornu, *Z. Chem. Ind. Kolloide,* **4**: 187. 1909. (Not in Dana.)
Sodium, dispersoidal.....**Na**	First suggested by Elster and Geitel to be the cause of color of blue halite, *Ann. Phys. Chem.,* **62**: 559. 1897; this has been confirmed by ultramicroscopic study and by successful synthetic experiments, as shown especially by Goldstein, *Nature,* **94**: 494. 1914. (Not in Dana.)
Potassium, dispersoidal.....**K**	Suggested to be the cause of color of blue sylvite, by analogy with the preceding substance, by Cornu, *Centr. Min. Geol.,* **1907**, 168; this has been confirmed as in the preceding instance. (Not in Dana.)
Calcium, dispersoidal.....**Ca**	Suggested to be the cause of color of certain fluorites by Doelter, *Sitzungsb. Akad. Wiss. Wien,* **1908**, 1312. (Not in Dana.)

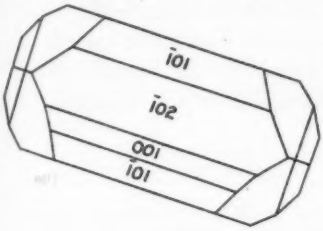
MINERALOGY.—*The crystal form of spencerite.* T. L. WALKER, Royal Ontario Museum of Mineralogy, Toronto.

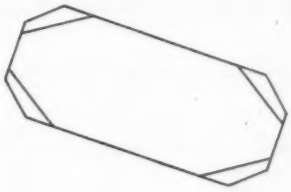
The new mineral spencerite—$Zn_3(PO_4)_2 . Zn(OH)_2 . 3H_2O$—was described by the author in 1916.[1] The material then available was obtained from the H. B. mine near Salmo, British Columbia. It is remarkable for its purity but is wholly in the massive form. From an optical examination it was found to be monoclinic and polysynthetically twinned, the twinning plane and composition face being the orthopinacoid. Plates parallel to the best cleavage, accepted as the orthopinacoid, showed an interference figure with the acute bisectrix nearly normal to this cleavage. Such plates when etched yielded etch figures symmetrical about only one plane. From these observations the author concluded that the mineral is monoclinic.

Spencerite occurs along with other oxidized zinc ores, forming the cores of stalactitic growths, the outer zone of which is always calamine. The spencerite being relatively soluble, the periphery of the spencerite core has as a rule been dissolved, leaving a space between the more soluble core and the resistant calamine.

[1] Mineralog. Mag., **18**, p. 76.

Under the circumstances the survival of crystals of the phosphate was hardly to be expected.





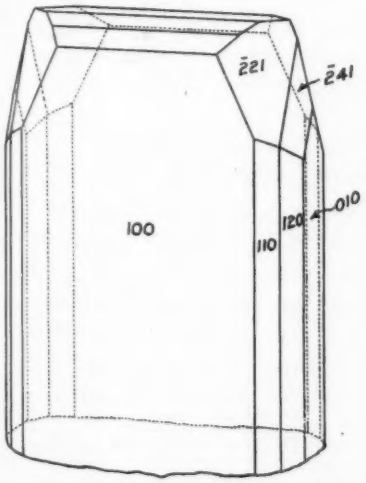


Fig. 1. The crystal is twinned on (100) and as a result of the twinning the forms (241) and (221) are each represented by four faces, thus giving the crystals a pseudorhombic appearance.

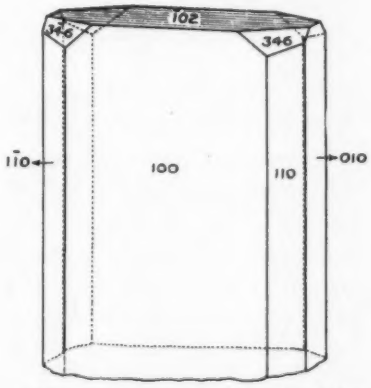


Fig. 2. Crystals of this type exhibit twinning in the duplication of the terminal faces, (346) being represented by four faces while the two faces of (102) occur as striations on a large plane nearly coinciding in direction with a rhombic basal pinacoid.

Some specimens of this mineral recently obtained from the original locality contain small druses lined with sharp crystals of spencerite, the preservation of the crystals being apparently due to the cavities having been completely sealed up by calamine.

The crystals are very small, few exceeding 2 or 3 mm. in length. They are tabular in habit and in color, luster, and habit closely resemble small, bright crystals of calamine. The crystals, though small, are admirably suited for accurate measurements. The conclusions regarding the crystal form contained in the original contribution are confirmed, since the mineral is

TABLE 1

FORM	NUMBER OF MEASUREMENTS	ϕ		ρ	
		Measured	Calculated	Measured	Calculated
120	12	29° 34′	29° 32′	90°	90°
230	2	35° 50′	37° 04′	90°	90°
110	11	48° 32′	48° 34′	90°	90°
520	6	71° 07′	70° 34′	90°	90°
010	6	0	0	90°	90°
100	6	90°	90°	90°	90°
001	4	89° 56′	90°	26° 52′	26° 47′
$\bar{1}04$	2	90°	90°	11° 20′	11° 30′
$\bar{1}02$	3	90°	90°	5° 17′	5° 36′
$\bar{3}04$	1	89° 57′	90°	21° 07′	21° 47′
$\bar{1}01$	3	89° 53′	90°	34° 55′	35° 02′
$\bar{2}01$	1	89° 14′	90°	61° 30′	62° 20′
023	1	35° 40′	35° 26′	40° 57′	41° 03′
021	4	13° 30′	13° 21′	65° 32′	65° 25′
121	5	38° 36′	38° 48′	69° 53′	69° 53′
346	3	56° 58′	57° 22′	53° 05′	52° 46′
$\bar{1}11$	2	32° 55′	33° 23′	51° 49′	51° 53′
$\bar{1}21$	6	18° 06′	18° 14′	65° 48′	65° 57′
$\bar{2}21$	4	41° 52′	41° 52′	70° 41′	70° 43′
$\bar{2}41$	4	24° 23′	24° 08′	77° 53′	77° 54′

found to be monoclinic, with polysynthetic twinning on the pinacoid (100).

There are two types of crystals, the first of which is represented in figure 1. The peculiarity of this type is the prominence of the pyramid $\bar{2}21$ with relatively small terminal faces of the orthodiagonal zone. Crystals of the second type are terminated by

what appears to be a large face intersecting the prism edges at 90°. A careful examination shows that this large terminal plane is striated, the faces of the striations belonging to the form ($\bar{1}02$). (See fig. 2.) All the crystals measured are twinned and show faces of the two constituent individuals.

The polar elements derived from the measurements are as follows:

$$p_o = 1.0512; q_o = 0.9501; e = 0.45071; \mu = 63°13'$$

corresponding to the axial ratios,

$$a:b:c :: 1.0125:1:1.0643; \beta = 63°13'.$$

In table 1 are indicated the forms observed and the polar angles ϕ and ρ measured and calculated for the elements indicated above. The number of faces observed for each form on the four crystals measured is shown in the second column.

ETHNOLOGY.—*A prehistoric stone mortar from southern Arizona.*[1] J. WALTER FEWKES, Bureau of American Ethnology.

Prehistoric buildings in the Gila Valley differ from those of southern Colorado and New Mexico in materials employed, form, and details in construction and arrangement of sacred and other rooms. There are less pronounced differences in ceramics, implements, and household utensils of the two areas. The acquisition of a fine, characteristic stone mortar from near Casa Grande has led me to describe it and incidentally to refer to a feature in this object not shared with mortars from the true Pueblo area.

A short time ago I obtained from Mr. John Miller, one of my workmen at the Casa Grande ruin in 1907, a stone mortar of more than ordinary interest on account of its artistic character. This object was found 5 miles south of the Picacho reservoir, Arizona, where there are traces of ancient settlements. It is made of a light-colored volcanic stone of circular shape and has a flat base with a cavity or depression on the opposite face. The

[1] Published by permission of the Secretary of the Smithsonian Institution.

remarkable feature is a rattlesnake sculptured in high relief on the margin (fig. 1).

The body of this animal almost completely surrounds the mortar, the anterior end of the body being coiled, and the tail ending in four rattles and a button. The head projects from the coiled part of the body and is flat above, indented with three pits, two of which were intended for eyes. The body is covered with a cross hatching of incised lines representing scales, and the mouth is a horizontal slit. From the top of the nose to the opposite rim the diameter measures 4¼ inches and the depth of the cavity three-fourths of an inch.

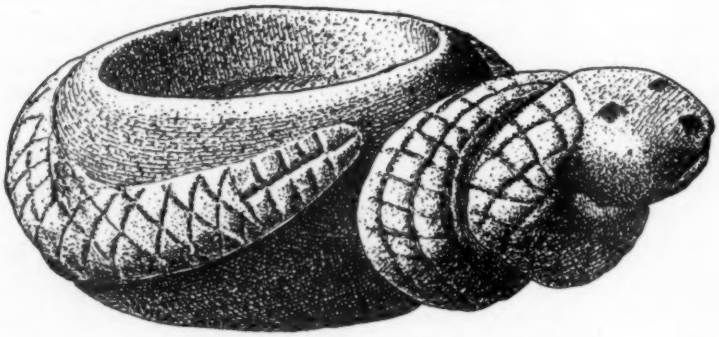


Fig. 1. Snake mortar. Diameter 4¼ inches.

The above specimen is now in the Museum of the American Indian, Heye Foundation, New York City.

Mortars made of stone carved in animal forms are not rare in the Gila Valley, although outside of this area they are, so far as known, rarely found in numbers. There are many known examples of mortars of round, oblong shapes, sometimes with prolongations on the larger axes, representing conventionalized organs, but in others the intended form is so realistic that the animal can be roughly identified.

One of the best of these was found in Compound B of the Casa Grande group and figured as an idol in my report[2] on that ruin.

[2] Twenty-eighth Annual Report of the Bureau of American Ethnology, plate 47.

Others in form of frogs and turtles may be seen in local collections or figured in descriptions of Gila Valley antiquities. I recall two mortars with serpentine bodies cut on their margins, neither of which is as well made as the specimen above described. Mortars from this region in the form of other animals are also known. A mortar from the San Pedro Valley resembling a horned quadruped is figured in my paper on Prehistoric Ruins of the Gila Valley,[3] and there is in the Museum of the University of Arizona a specimen similar to the last mentioned. Mr. Warren K. Moorehead[4] figures a mortar resembling a turtle or some reptile. In all these the depression or cavity of the mortar is situated on the back of the animal, whereas in the snake mortars, the snake surrounds or embraces the mortar.

It will be noticed that these specimens have a depression or cavity which has led to their identification as mortars. In this respect they differ from paint palettes, likewise prehistoric, found in numbers in the Gila region. The stones upon which paint is ordinarily ground among the Pueblos are flat, undecorated slabs, without cavities, or generally only shallow depressions. Similar palettes from the Gila are made with more care and their margins are commonly bands decorated with incised geometrical designs or even, in one or two known instances, with figures of snakes or other animals. They are ordinarily rectangular in form, but other shapes also occur, such as circles and ovals. A figure of one of these tablets or palettes in the shape of a bird was obtained from Pueblo Viejo on the Upper Gila, and published in my account of Two Summers' Work in Pueblo Ruins.[5] A typical hitherto undescribed rectangular paint palette which was plowed up by a farmer on the north side of the Gila, 6 miles from Florence, Arizona, is shown herewith (fig. 2). This is a thin slab of rock with a marginal frame covered with incised crosshatched lines recalling the conventional way of representing scales of a snake. This specimen, like the snake mortar, is

[3] Smithsonian Miscellaneous Collections, Quarterly Review, **5**, fig. 75*a*.

[4] The Stone Age in North America, **2**, fig. 416.

[5] Twenty-second Annual Report of the Bureau of American Ethnology; also Preliminary Report in Smithsonian Miscellaneous Collections, 1896.

also in the Museum of the American Indian, Heye Foundation. Similar paint palettes with modifications in decorations are widely distributed; those from the mound-builders sometimes bear incised figures of serpents in their surfaces. As a paint palette admits of few variations in form it is not strange that similar shapes occur likewise among Pueblos and mound-builders,[6] and, especially in predynastic times, in Egypt[7] (fig. 3).

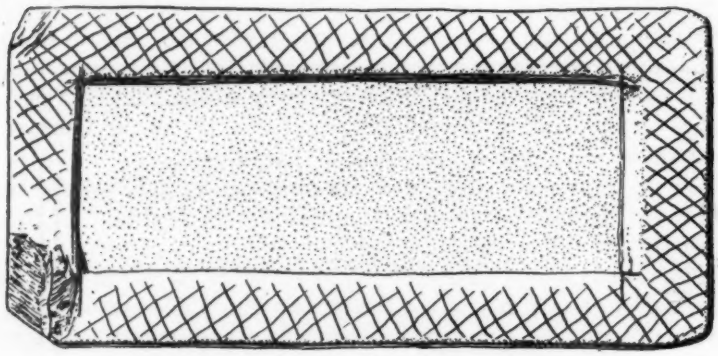


Fig. 2. Paint palette. Size 2¼ by 4½ inches.

Everything used by a primitive people in their ceremonies has, from that fact, a magic power and the stones upon which pigments are ground by the Pueblos partake in a measure of this power. The symbolic figures that decorate paint palettes no doubt increase, in their opinion, the efficacy of the pigment. A similarity in the way these palettes are regarded in the Old and the New World is a good instance of thought convergence.

A few objects of stone supposed to be pestles or paint grinders, possibly used with these pigment palettes, are known from the Gila. One of these from Casa Grande has the form of a "coiled serpent,"[8] a highly suggestive fact taken in connection with a snake-decorated mortar.

[6] HOLMES, W. H., *Certain notched or scalloped stone tablets of the mound builders.* Amer. Anthropol., **8**, No. 1, fig. 9. Jan.–March, 1906.

[7] BATES, ORIC. *Ancient Egyptian fishing.* Harvard African Studies, No. 1.

[8] Twenty-eighth Annual Report of the Bureau of American Ethnology, pl. 48, fig. 1.

The custom of decorating mortars and paint grinders with animal figures points to Mexican rather than Pueblo customs and kinship. The serpent as an element in sculpture is especially Mexican, although figures of the rattlesnake occur on pipes and stone or shell objects throughout the mound-builders and Pueblo areas; while painting of the same on pottery, and as pictographs ascribed to prehistoric times, are no less frequent. The cult of the Plumed Snake or, as some prefer to call it, the Horned Snake, occurs so constantly in Indian mythology and ritual that this

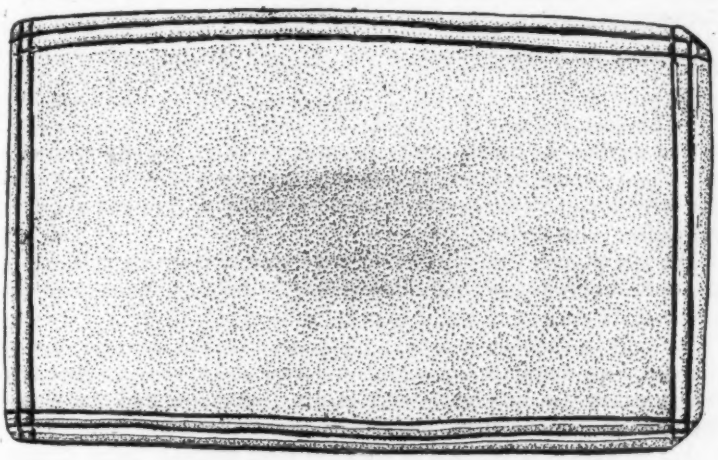


Fig. 3. Egyptian slate palette. Size 3½ by 5½ inches.

being is frequently represented on ceremonial paraphernalia; but there are, so far as I know, few if any mortars of prehistoric Indians of North America with sculptured figures that artistically excel the snake mortar above figured. The snake-entwined mortar is another evidence that the prehistoric culture of the Gila had a close relationship to that of the aborigines of northern Mexico.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

TECHNOLOGY.—*Temperature measurements in Bessemer and open hearth practice.* GEORGE K. BURGESS. Bureau of Standards Technologic Paper No. 91. Pp. 29. 1917.

The problem of temperature measurement and pyrometric control of furnace casting and ingot teeming temperatures is shown, by a series of observations taken in several steel plants, to present no serious difficulties or uncertainties.

For this purpose the most satisfactory type of instrument is one of the optical pyrometers using monochromatic light and permitting observation of streams of metal from a distance.

It is shown that the necessary corrections to the observed optical pyrometer readings for emissivity of metal and oxides to give true temperatures, are sufficiently well known, but there may be uncertainty in the case of liquid slags.

For streams of liquid iron or steel the most probable value of emissivity to take, with a pyrometer using red light of wave length $\lambda = 0.65\ \mu$, is $e = 0.40$, corresponding to a correction of 139° for an observed temperature of 1500°C. The value of e for liquid slags is usually about 0.65 but varies with the composition of the slag. A table of emissivity corrections is included in the text.

It is believed that a continuous, systematic following of the temperature by the methods outlined in the paper would show the possibility of improvements, and give a greater certainty of the production of the desired quality of product. G. K. B.

REFERENCES

Under this heading it is proposed to include, by author, title, and citation, references to scientific papers published in or emanating from Washington. It is requested that authors cooperate with the editors by submitting titles promptly, following the style used below. These references are not intended to replace the more extended abstracts published elsewhere in this JOURNAL.

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE PHILOSOPHICAL SOCIETY OF WASHINGTON

The 787th meeting was held at the Cosmos Club, March 31, 1917. President BUCKINGHAM in the chair; 36 persons present. The minutes of the 786th meeting were read in abstract and approved.

The following resolution was unanimously adopted:

Resolved: That the Philosophical Society of Washington endorses the movement to extend the use of the metric system and commends the efforts of the American Metric Association to this end.

Mr. FREDERICK BATES and Mr. F. P. PHELPS gave an illustrated paper on *The rotation of the plane of polarization in quartz and iron at high temperatures.*

Curves showing the results of precision measurements for both the natural and the magnetic rotation of the plane of polarization in quartz for a temperature range from 20°C. to 1000°C. were exhibited. Quartz recrystallizes at about 575°C. changing from α to β quartz. The curve for the variation of the natural rotation with the temperature makes a right angle turn at this point and shows evidence of a discontinuity. In contrast to the natural rotation the magnetic rotation shows no change at 575° and has no temperature coefficient. For measuring the rotations a large Weiss, water-cooled electromagnet was used. The furnace was placed between the poles of the magnet and the temperature was obtained by means of a standard thermocouple. Monochromatic light of high intensity was passed through the plate parallel to the magnetic field. Similar curves for the magnetic rotation in films of electrolytic iron and iron oxides were also shown. The results indicate that the optical phenomena disappear at the temperature at which the metal loses its magnetic properties.

Discussion. The paper was discussed by Messrs. WHITE and WRIGHT. Mr. G. K. BURGESS spoke of the possibility of harmonizing results showing the magnetic rotation of films of iron which had become oxidized, by disregarding the oxygen and considering only the iron present.

Mr. F. E. WRIGHT gave an illustrated paper on *The application of polarized light to the study of opaque substances.*

Mr. P. V. WELLS gave an illustrated paper on *A standard of turbidity.* The speaker described briefly the physical properties of turbid media, pointing out that such media are usually in a critical state. Their most striking characteristic is that of scattering light, the effect vary-

ing rapidly with small changes in the other variables, such as temperature or pressure. The factors determining the intensity of the scattered light in the simple case of particles small compared with the wave length of the light were given after the treatment of Rayleigh.

Turbidimetry is chiefly concerned with the measurement of the mass of suspended matter, but, as this is small and its accurate determination difficult, optical measures have frequently been adopted for rapid work. The most definite of these is the intensity of the light scattered in a fixed direction from a layer of turbid medium of definite thickness, illuminated by a parallel incident beam. The logical measure would be the ratio of the scattered and incident intensity. Provisionally, however, the scattered intensity was compared with the intensity of the light diffusely reflected normally from a magnesia surface with the same parallel beam incident at 45°. The magnesia surface was made by depositing the smoke from burning magnesium ribbon upon thin plate glass. The magnesia-glass surface was used because its direction could be determined. It was accurately reproducible. A turbidimeter was described, by means of which these measurements could be made. The readings obtained with doubly distilled water, with turbid liquids, and with air, both pure and vitiated with smoke, were given.

Discussion. Mr. WRIGHT inquired as to the possibility of using the scattering of a beam of polarized light, as measured by the amount of light emerging polarized at right angles to the plane of the entering beam, as an indication of turbidity. Mr. WELLS stated that such effects would vary with the size of the suspended particles. Mr. MERWIN inquired as to the distribution of the light scattered from the magnesia reference plate. Mr. WELLS stated that it had not been measured, but that it probably followed Lambert's law closely. Mr. BATES spoke of the difficulty of producing a perfectly clear fluid, with especial reference to some attempts to remove all suspended particles from oil.

The 788th meeting was held at the Cosmos Club, April 19, 1917. President BUCKINGHAM in the chair; 85 persons present.

The entire evening was devoted to hearing an address by Dr. IRVING LANGMUIR on *The constitution of liquids.* (No abstract.) A paper dealing with the subject matter presented will be found in the Proc. National Acad. Sci., **3**: 251–257. 1917.

Discussion. The paper was discussed by Messrs. SPARROW, BUCKINGHAM, SWANN, and HERSEY, and by Messrs. T. C. MENDENHALL and R. A. MILLIKAN with especial reference to the questionable but persistent idea of a spherical atom.

The 789th meeting was held at the Cosmos Club, April 28, 1917. Vice President HUMPHREYS in the chair; 39 persons present. The minutes of the 787th and 788th meetings were read in abstract and approved.

The Secretary read the call for the first meeting of the Society and the list of charter members.

Mr. WILLIAM H. DALL delivered an address on *The origin and early days of the Philosophical Society of Washington.* The address will probably be published in full in this JOURNAL at a later date.

The Secretary read a letter from Mr. G. K. GILBERT, the second oldest member of the Society, conveying his best wishes and expressing regret that it was impossible for him to be present at the meeting.

Mr. F. W. CLARKE delivered an address on *The development of scientific societies in Washington.*

Interesting reminiscences of the early days of the society were offered by Messrs. HOWARD, FARQUHAR, WEAD, and BAUER.

The 790th meeting was held at the Cosmos Club, May 12, 1917 President BUCKINGHAM in the chair; 28 persons present. The minutes of the 789th meeting were read in abstract and approved.

Messrs. I. G. PRIEST and C. G. PETERS gave an illustrated paper on *An interferential method for measuring the expansion of very small samples.* This paper describes a method requiring as a sample only *one* small pin about 5 mm. in diameter by 10 mm. long, or even of smaller dimensions. Briefly the outline of the method is as follow:

1. One of a pair of nearly (but not quite) parallel interferometer mirrors is supported at one point by the sample and at two other points by a standard substance of known expansivity.

2. Any difference in the expansivity of the sample and the standard causes the interference fringes to change their *widths* with changing temperature. This change in width is measured, and from it the relative expansion is computed.

Noteworthy advantages of this method over the Fizeau-Pulfrich method are:

1. Smallness of sample required.

2. Elimination of the difficulty of obtaining the interference fringe data. It is not necessary to count the passage of fringes during the temperature change nor to make measurements on fringes of more than one wave length.

3. The very troublesome correction for change in the refractive index of air with temperature is eliminated.

It is expected that a fuller description of this method will appear later as a Scientific Paper of the Bureau of Standards.

Discussion. The paper was discussed by Messrs. BUCKINGHAM and HUMPHREYS.

By invitation Mr. J. D. EDWARDS gave an illustrated paper on *The rapid determination of gas density.*

Because of their importance in connection with orifice meter measurements and other technical and scientific problems, methods for the rapid determination of gas density have been investigated at the Bureau of Standards.

The effusion method which has been widely used for this purpose has been shown to be unreliable, errors of over 10 per cent not being unusual in practice. A study of the theory of the effusion process has revealed the main sources of error in this method. The effusion method under the most favorable conditions can probably not be relied on to better than 1 or 2 per cent.

In order to secure precise results a specific gravity balance employing an indirect weighing method was developed; this enables one to secure results accurate to about 0.2 per cent. This apparatus is convenient to use, may be made portable, and requires no preliminary calibration.

Discussion. The paper was discussed by Messrs. PRIEST, HERSEY, SWEET, BUCKINGHAM, and HUMPHREYS.

Informal communications: Mr. BUCKINGHAM outlined a theory accounting for the errors in the effusion method of determining gas densities.

Mr. C. A. BRIGGS exhibited two combination time and percussion caps for shrapnel shells of types now in use on the Russian battle front.

Mr. H. F. STIMSON exhibited a 2-stage mercury vapor condensation pump for operating between about 4 cm. and 0.0004 mm. of mercury. The low pressure stage is built with a long nozzle of the De Laval type and the high pressure with a short nozzle. In each nozzle the ratio of the higher to the lower pressure is maintained above the critical value of about 2, and the velocity of the vapor in the nozzle is greater than the velocity of sound.

DONALD H. SWEET, *Secretary.*

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